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Can Computed Tomographic Gastrography and Multiplanar Reformatting Aid the Laparoscopic Surgeon in Planning a Gastric Resection? A Pictorial Essay

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Abstract

Purpose: To assess the value and feasibility of computed tomographic gastrography and multiplanar reformatting in the preoperative evaluation of patients undergoing laparoscopic gastric resection.
Materials and Methods: Fourteen patients with gastric lesions were included in the study. A supine scan was performed after a hypotonic drug, an effervescent agent, and intravenous contrast. This was followed by delayed prone and decubitus scans. We created multiplanar reformats, transparency rendered images, and endoluminal images. The tumours were localized, and distances were measured to the esophagogastric junction and the pylorus.
Results: Eleven patients underwent resections. Seven had laparoscopic wedge resections for aberrant pancreas (1 patient), carcinoid (1), Castleman disease (1), and gastrointestinal stromal tumours (GISTs) (4). One patient had an open subtotal gastrectomy for carcinoma due to adhesions. One had a hand-assisted sleeve resection for a gastrointestinal stromal tumour. Two had hand-assisted total gastrectomies for carcinoma and a GIST. For surgical planning, the surgeon rated the imaging extremely useful in 7 and useful in 4. Imaging was extremely useful or useful to localize laparoscopically invisible tumours in 6 patients and to relate tumours to the esophagogastric junction or pylorus and to assess localized vs extensive resection in 8. Correlation was excellent between the preoperative imaging and the intraoperative findings.
Conclusions: Computed tomographic gastrography and multiplanar reformatting are useful aids in preoperative planning of laparoscopic gastric resections.

Résumé

Objet : Estimer la valeur et la faisabilité de la gastrographie tomodensitométrique et de la reconstruction multiplanaire pour l'évaluation préopératoire des patients devant subir une résection gastrique par laparoscopie.
Matériel et méthodes : L'étude a été menée auprès de 14 patients souffrant de lésions gastriques. Une tomodensitométrie en position couchée a été réalisée après l'administration d'un médicament hypotonique, d'un agent effervescent et d'un produit de contraste par voie intraveineuse. Des acquisitions tardives ont ensuite été effectuées en position ventrale et décubitus. Nous avons créé des reconstructions multiplanaires, des images transparentes et des images endoluminales. Les tumeurs ont été localisées et les distances jusqu'à la jonction oesophago-gastrique et au pylore ont été mesurées.
Résultats : Des résections ont été réalisées chez 11 patients. Ainsi, sept patients ont subi une résection cunéiforme par laparoscopie : un pour un pancréas aberrant, un pour un carcinoïde, un pour la maladie de Castleman et quatre pour des tumeurs stromales gastro-intestinales. Un patient a subi une gastrectomie subtotale ouverte pour un carcinome dû à des adhérences. Un patient a subi une résection en manchon d'une tumeur stromale gastro-intestinale, assistée manuellement en raison d'adhérences. Deux patients ont subi une gastrectomie totale assistée manuellement pour un carcinome et tumeur stromale gastro-intestinale. Le chirurgien a jugé les images très utiles à des fins de planification dans sept cas et utiles dans quatre cas. Les images ont facilité le repérage des tumeurs invisibles à la laparoscopie chez six patients et la

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localisation des tumeurs par rapport à la jonction oesophago-gastrique et au pylore. Elles ont également permis de déterminer si une résection locale ou totale s'imposait pour huit patients. La corrélation entre l'imagerie préopératoire et les résultats peropératoires était excellente.
Conclusions : La gastrographie tomodensitométrique et la reconstruction multiplanaire s'avèrent très utiles pour la planification préopératoire des résections gastriques par laparoscopie.

Key Words: Computed tomographic gastrography; Virtual gastroscopy; Gastric surgery; Gastric computed tomography

Computed tomography (CT) has become a valuable imaging study in planning a resection for tumours of the stomach [1−6]. As more surgeons have gained expertise in laparoscopic surgery and recognized a role for limited gastric resection for some tumours, preoperative CT has become more essential [7,8]. CT gastrography (CTG or virtual gastroscopy) offers an overview of the normal and abnormal gastric mucosa of the same high quality as achievable with CT colonography (CTC or virtual colonoscopy). Multiplanar reformatting (MPR) enables confident visualization and characterization of tumours in multiple planes and assessment of their relation to the esophagogastric junction and pylorus [1−6,9,10]. We are carrying out an ongoing study to assess the value and feasibility of adding CTG and MPR to the conventional abdominal staging CT in the preoperative evaluation of patients undergoing laparoscopic gastric resection and to describe our initial experience with a prospective trial of 14 patients.

Materials and Methods

Between July 2008 and September 2009, we examined 14 patients with gastric tumours or aberrant pancreas. The patients were referred by a single surgeon (T.G.) with extensive experience in laparoscopic gastric surgery; these patients had already undergone endoscopy and had been scheduled for preoperative CT, and were considered candidates for laparoscopic gastric resection. The surgeon selected patients for CTG for one or more of the following reasons: it would aid in completing a laparoscopic resection, thus avoiding conversion to an open resection, it would aid in avoiding extensive mobilization or endoscopic ultrasound to visualize the tumour, or it would aid in performing a limited or wedge resection for the 10 patients with lesions other than carcinoma. CTG is an established technique at our hospital, and institutional review board approval was not required. We followed our practice with CTC in that patients received an explanation from a radiologist and gave verbal consent for the procedure. All the studies were performed with a 64-detector Light Speed CT scanner (GE, Mississauga, ON). The patients fasted overnight for a morning examination and from 7 AM for an afternoon examination. All the patients received an intravenous hypotonic medication, usually Buscopan (hyoscine butylbromide; Sandoz, Boucherville, QC) 20 mg or glucagon (Lilly, Toronto, ON) 1 mg when Buscopan was contraindicated. This was followed by an effervescent agent EZ Gas 4 g (EZEM Canada, Anjou, QC) with a minimal amount of water. The patients were scanned in the supine and prone positions and one decubitus position, left decubitus for distal corporal and antral lesions, and right decubitus for fundal and proximal corporal lesions. The effervescent agent was repeated before the prone or decubitus scan as necessary.

The scanning parameters were the following: 120 kV, 250-365 mA, rotation time of 0.50 seconds, speed of 39.4 mm per rotation, pitch of 0.984:1, and 0.6-mm collimation and reconstruction, For the first scan in the supine position 110-120 mL Visipaque 270 (iodixanol; GE) were given intravenously, and the tube current was 365 mA. The abdomen was scanned from the diaphragm to the pubic symphysis 80 seconds after the start of the contrast injection at 3 mL/s for the portal venous phase in the first 10 patients. From the patient 11 onward, we added an arterial phase with the scan limited to the upper abdomen for vascular road mapping. We increased the injection rate to 4 mL/s and used contrast bolus tracking to obtain the arterial phase for 5 seconds and the portal venous phase for 35 seconds after the aortic density at L2 exceeded 120 HU. For the second and third scans in the prone and decubitus positions, the scans were limited to the upper abdomen and the tube current was decreased to 250 mA. From the axial images, we reformatted coronal, sagittal, and oblique planes; created endoluminal images and volume rendered (VR) images with the CTC software on an ADW work station (GE); and transmitted these to PACS. All CTs were reviewed by 2 radiologists (A.Z. and W.D.) and reported by a single radiologist (A.Z.) after consensus had been reached. We localized and characterized all tumours and measured their distances along the gastric wall to the esophagogastric junction for proximal tumours and to the pylorus for distal tumours. If the prone or decubitus position was the best position for localization and measurement, then we also reported the location and distances in the supine position, which is the patient's position during surgery. We examined the entire mucosal surface of the stomach for evidence of other lesions and constructed arterial road maps for the last 4 patients [11]. Finally, we looked for evidence of tumour spread beyond the stomach and for metastases.

Results

The median age of our 14 patients was 59 years, with a range of 42-86 years. There were 8 men and 6 women. There were 6 stromal tumours (GISTs), 4 carcinomas, 2 aberrant pancreas, 1 carcinoid tumour, and 1 Castleman

disease. Eleven patients had resections. Seven of the 11 patients had endoscopy, CT, and surgery performed within 7 weeks; of these 7 patients, 2 with carcinoma had all 3 procedures performed within 19 days. Three patients with lesions other than carcinoma had all 3 procedures performed within 4 months, and 1 patient with a stromal tumour stable on endoscopy and endoscopic ultrasound had CT and surgery delayed for a year due to a stroke. Seven patients had laparoscopic wedge resections for aberrant pancreas (1), carcinoid (1), Castleman disease (1), and stromal tumours (4). There was one conversion from laparoscopy to an open subtotal gastrectomy and gastrojejunostomy for carcinoma because of extensive adhesions from a cholecystectomy. One had a hand-assisted laparoscopic sleeve resection for a stromal tumour. Two had hand-assisted laparoscopic total gastrectomies with Roux-en-Y reconstructions for carcinoma and stromal tumour. Three patients did not have resections; these patients are described in Table 1.

The CT studies were of good quality in all 14 patients. For surgical planning in the 11 patients who underwent resections, the surgeon rated the imaging extremely useful in 7 and useful in 4. Imaging was considered extremely useful when it enabled the surgeon to complete a laparoscopic resection rather than convert to an open resection. Imaging was considered useful when it enabled the surgeon to avoid extensive mobilization or resorting to endoscopic ultrasound to visualize the tumour. Imaging was extremely useful in 7 patients and useful in 4 patients; it was extremely useful or useful to localize laparoscopically invisible tumours in 6 and to relate tumours to the esophagogastric junction or pylorus and to assess localized vs extensive resection in 8. Correlation was excellent between the preoperative imaging and the intraoperative findings in the 11 patients who underwent a resection. Five patients are presented below in detail.

Patient 3: Aberrant Pancreas With a Negative Abdominal CT 7 Months Earlier

A 49-year-old woman presented with nonspecific intermittent upper-abdominal pain and nausea for several years. An abdominal CT 7 months earlier was reported as negative but, in retrospect, showed gastric antral mural thickening. Gastroscopy showed an umbilicated submucosal mass on the greater curvature of the gastric antrum, and a repeat CT showed a mass of soft-tissue density in this location. Endoscopic ultrasound showed a component arising in the muscularis propia and a component with a ductular structure arising in the submucosa, a finding highly suggestive of a pancreatic rest and confirmed by biopsy. A CT with CTG and MPR showed a lobulated, umbilicated, and enhancing mass on the greater curvature of the prepyloric antrum 1.8 × 1.4 cm, with a height of 1.2 cm (Figure 1). The remainder of the stomach appeared normal. The surgeon evaluated the imaging as useful, and laparoscopic wedge resection was performed.

Patient 6: Adenocarcinoma With a Negative Abdominal CT Less Than 1 Month Earlier

An 86-year-old woman presented with diarrhoea and a 4.54 kg (10 lb) weight loss over 3 weeks. Colonoscopy and a conventional abdominal CT were negative. Gastroscopy showed a malignant-appearing ulcer on the anterior wall of the distal gastric corpus and biopsy-confirmed adenocarcinoma. A repeat CT with CTG and MPR showed an irregularly shaped, lobulated polypoid tumour on the anterior wall of the gastric corpus towards the lesser curvature, which was 2.7 × 1.8 cm, with a height of 1.1 cm (Figure 2). The remainder of the stomach appeared normal. The surgeon evaluated the imaging as useful; at surgery, it did not appear that a partial or subtotal gastrectomy would be curative, and a laparoscopic total gastrectomy with a Roux-en-Y reconstruction was performed.

Patient 7: Laparoscopically Invisible Stromal Tumour

A 62-year-old woman presented with vague upper-abdominal pain for 1 month and upper-gastrointestinal bleeding. Gastroscopy showed an extramucosal mass with a small ulcer and otherwise normal-appearing overlying mucosa on the posterior wall of the mid gastric corpus. Endoscopic ultrasound showed it to arise in the muscularis propia, a finding highly suggestive of a stromal tumour. A CT with CTG and MPR showed a 3.9 × 3.8 × 3.7-cm mass in the same location, with approximately half projecting intraluminally and half projecting extramurally. The intraluminal part of the mass that was seen at gastroscopy was 3.8 × 2.6 cm, with a height of 2.2 cm vs 3.7 cm for the height of the entire mass (Figure 3). The remainder of the stomach appeared normal. The tumour was not initially identifiable laparoscopically because of its posterior location, but the CT enabled precise localization. The surgeon evaluated the imaging as extremely useful, and laparoscopic wedge resection was performed.

Patient 11: Stromal Tumour Arising in an Incarcerated Hiatal Hernia

A 65-year-old man presented with melena and previous aspirin use. Gastroscopy showed a large hiatal hernia and an extramucosal umbilicated mass arising from the herniated somach. Endoscopic ultrasound showed it to arise in the muscularis propia and to be mainly extramural, findings highly suggestive of a stromal tumour. A CT with CTG and MPR showed a lobulated and umbilicated 4.2 × 3.9 × 3.4-cm extramucosal mass with a small intraluminal component on the lesser curvature approximately 4 cm from the esophagogastric junction. The intraluminal part of the mass, which was seen at gastroscopy, was 2.6 × 2.5 cm, with a height of 1.4 cm vs 4.2 cm for the height of the entire mass (Figure 4). The remainder of the stomach appeared normal. The surgeon evaluated the imaging as extremely useful, and laparoscopic

Table 1
Results of imaging, surgery, and outcomes in 14 patients

Patient no./sex/age (y)	Operative evaluation of imaging	Resection performed or other outcome	Final fiagnosis	Comments
1/M/60		No resection	Aberrant pancreas on anterior wall of antrum	Endoscopic follow-up
2/M/72	Useful	Open subtotal gastrectomy and gastrojejunostomy	Adenocarcinoma on greater curve of distal corpus with perigastric nodal metastasis	Laparoscopic resection not possible because of adhesions; the patient died 2 y after resection of metastatic carcinoma
3/F/49 (Figure 1)	Useful	Laparoscopic wedge resection	Aberrant pancreas on the greater curve of antrum	
4/M/72	Tumour studding of peritoneum and small bowel in addition to CT findings, ascites developing over 4 wk after CT to surgery; imaging was useful in predicting unresectability	No resection, feeding jejunostomy	Diffuse adenocarcinoma of antrum and pylorus, with extension into perigastric fat and omental and aortocaval nodal metastases	Tumour unresectable at surgery; the patient was referred to medical oncology service
5/M/40		No operation	Diffuse adenocarcinoma of antrum, pylorus, and first and proximal second duodenal segments, with extension into perigastric and paraaortic fat and pancreatic head and neck; common bile ductal obstruction; perigastric and mediastinal nodal; and pulmonary metastases	Tumour considered unresectable by CT criteria; surgery was not performed; the patient was referred to medical oncology service
6/F/86 (Figure 2)	Useful	Laparoscopic hand-assisted total gastrectomy and Roux-en-Y reconstruction	Adenocarcinoma on anterior wall of distal corpus	No recurrence 3 y after resection
7/F/62 (Figure 3)	Extremely useful	Laparoscopic wedge resection	GIST on posterior wall of mid corpus	
8/M/61	Extremely useful	Laparoscopic wedge resection	GIST on lesser curve of proximal corpus	Laparoscopic gastric wedge resection of GIST 4 y earlier
9/F/42	Extremely useful	Laparoscopic wedge resection	GIST on greater curve of antrum adjacent to pylorus	
10/M/56	Extremely useful	Laparoscopic hand-assisted total gastrectomy and Roux-en-Y reconstruction	GIST on posterior wall of mid corpus	
11/M/65 (Figure 4)	Extremely useful	Laparoscopic wedge resection and hiatal hernia repair	GIST on lesser curve of proximal corpus in incarcerated hiatal hernia	
12/F/57	Useful	Laparoscopic wedge resection	Carcinoid on the greater curve of the mid corpus	Remote jejunoileal bypass for obesity was left intact
13/F/57	Extremely useful	Laparoscopic hand-assisted sleeve resection	GIST on the posterior wall of the fundus adjacent to the esophagogastric junction	
14/M/52 (Figure 5)	Extremely useful	Laparoscopic wedge resection	Castleman disease on the lesser curve of the fundus adjacent to esophagogastric junction	Preoperative diagnosis of GIST, initial pathologic diagnosis of low-grade lymphoma

CT = computed tomography; GIST = gastrointestinal stromal tumour.

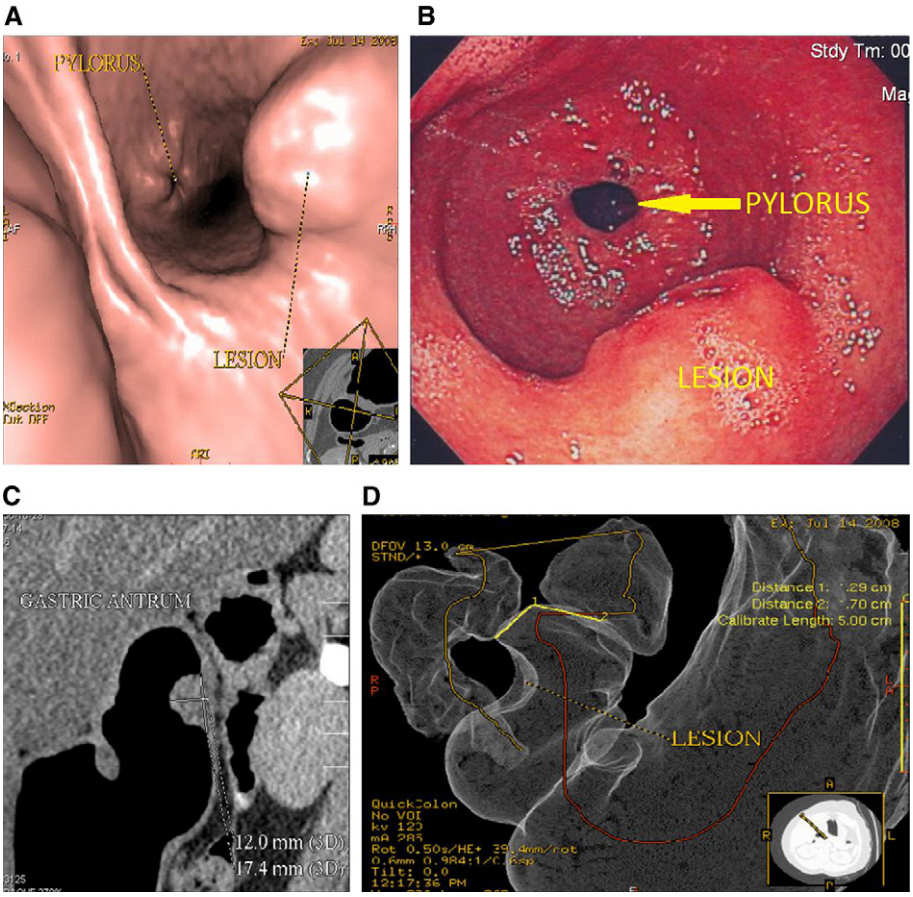

Figure 1. (A–C) Endoluminal image (A), gastroscopic image (B), and corresponding 2-dimensional sagittal scan (C), showing the tumour on the greater curvature of the prepyloric antrum. (D) Volume rendered image, showing the location of the tumour and the distance from the distal edge of the tumour to the pylorus. This figure is available in colour online at http://carjonline.org/.

reduction of the hiatal hernia and wedge resection were performed.

Patient 14: Castleman Disease Discovered Incidentally During Staging of a Left Renal Tumour

A 52-year-old man undergoing staging CT for a left renal cell carcinoma was found to have a mass arising from the lesser curvature of the stomach close to the esophagogastric junction. The patient was asymptomatic. Gastroscopy showed an extramucosal mass with normal-appearing overlying mucosa. Because of the CT and gastroscopic appearance, a stromal tumour was considered the most likely diagnosis. A CT with CTG and MPR showed a 4.7 × 4.2 × 3.6-cm extramucosal vascular mass with a small intraluminal component in the same location. The mass was supplied by a dilated left gastric artery and drained by a dialted left gastric vein. The intraluminal part of the mass, which was seen at gastroscopy measured 3.4 × 2.8 cm with a height of 1.0 cm vs 3.6 cm for the height of the entire mass (Figure 5). The remainder of the stomach appeared normal. The surgeon evaluated the imaging as extremely useful, and laparoscopic wedge resection was performed. The tumour had features suggestive of a low-grade B-cell lymphoma, but the final diagnosis was Castleman disease.

Conclusion

Our initial experience with 14 patients, of whom 11 have undergone gastric resection, suggests CTG and MPR to be useful adjuncts to the conventional abdominal CT in the preoperative planning of laparoscopic gastric resections. CTG and MPR can offer valuable information about gastric tumours, including morphology, location, size, both intraluminal and extramucosal components, distance of proximal lesions from the esophagogastric junction, distance of distal lesions from the pylorus, and assessment of localized vs extensive resection.

CTG is a noninvasive technique that produces endoluminal images and that can show subtle mucosal abnormalities, and is comparable in quality to optical gastroscopy [1–6,9,10,12–17]. CTG has a wider field of view, with no blind spots, and can approach lesions from more directions than can gastroscopy, and it can render more precise measurements of lesions. Volume rendered images provide a global orientation similar to an upper-gastrointestinal series, with which referring physicians are more familiar than with gastric CT. Because volume rendered images can be rotated into any plane, they complement MPR in the assessment of lesion morphology, size, location, and

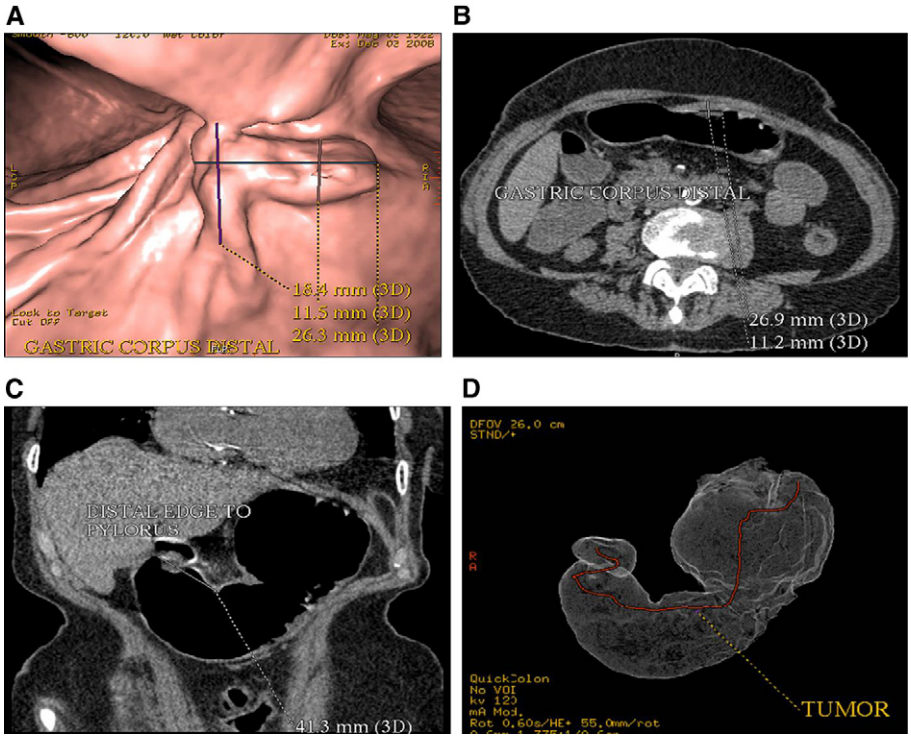

Figure 2. (A, B) Endoluminal image (A) and corresponding 2-dimensional axial scan (B), showing the tumour on the anterior corporal wall. (C) Multiplanar reformatting, showing the distance from the distal edge of the tumour to the pylorus. (D) Volume rendered image, showing the location of the tumour. This figure is available in colour online at http://carjonline.org/.

relationship to the esophagogastric junction and pylorus. MPR enables accurate staging of gastric tumours, including associated lymphadenopathy and distant metastases. Gastric lesions can be more confidently characterized by MPR than with the axial plane alone [1–6,9,10,12–17].

Compared with CTC, CTG has fewer problems with patient preparation, only requiring fasting, and with gaseous distension, only requiring an effervescent agent and water. CTG does have limitations. It has a steep learning curve and, like MPR, is time consuming. Unlike optical gastroscopy, CTG does not depict mucosal colour changes, is not sensitive for flat lesions, delivers ionizing radiation to the patient, and requires follow-up gastroscopic biopsy for any abnormalities it identifies [1–6,9,10,12–17]. Finally, the stomach is distended for CTG and MPR and is collapsed for surgery, and the location of the lesion at CT may not be identical to that at surgery.

The surgeon must sometimes make intraoperative decisions independent of the imaging findings. This happened in 4 patients. In the patient 2, a 72-year-old man with adenocarcinoma, laparoscopic resection was not possible because of postcholecystectomy adhesions. In patient 4, a 72-year-old man with adenocarcinoma, resection was not attempted because of tumour studding of the peritoneum and small

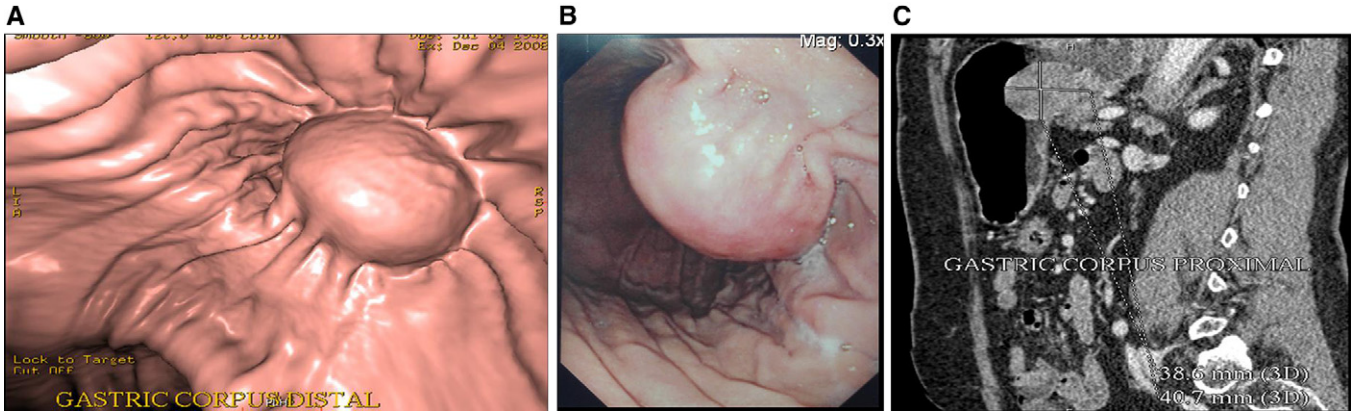

Figure 3. (A–C) Endoluminal image (A), gastroscopic image (B), and corresponding 2-dimensional sagittal scan (C), showing the tumour on the posterior corporal wall. This figure is available in colour online at http://carjonline.org/.

Figure 4. (A, B) Endoluminal image (A) and corresponding 2-dimensional axial scan (B), showing the tumour on the lesser curvature of the herniated stomach and the distance from the proximal edge of the tumour to the esophaogastric junction. (C) Volume rendered image, showing the location of the tumour. This figure is available in colour online at http://carjonline.org/.

bowel, which was not detected on the CT. In patient 6, an 86-year-old woman with adenocarcinoma, a total gastrectomy was performed because of concerns that the resection margin with a subtotal gastrectomy might be inadequate and that reoperation for a recurrence would be hazardous because of the patient's age and other comorbidities. In patient 10, a 56-year-old man with a stromal tumour, a total gastrectomy was performed because of concern that a subtotal gastrectomy would leave a gastric remnant with an inadequate blood supply in view of the tumour's size and proximity to the left gastric artery. If we had included vascular road mapping when this patient's CT was performed, then identification of the left gastric artery might have alerted the surgeon to this requirement before surgery.

Our initial study has been limited and has not provided sufficient data for statistical analysis. We gained little

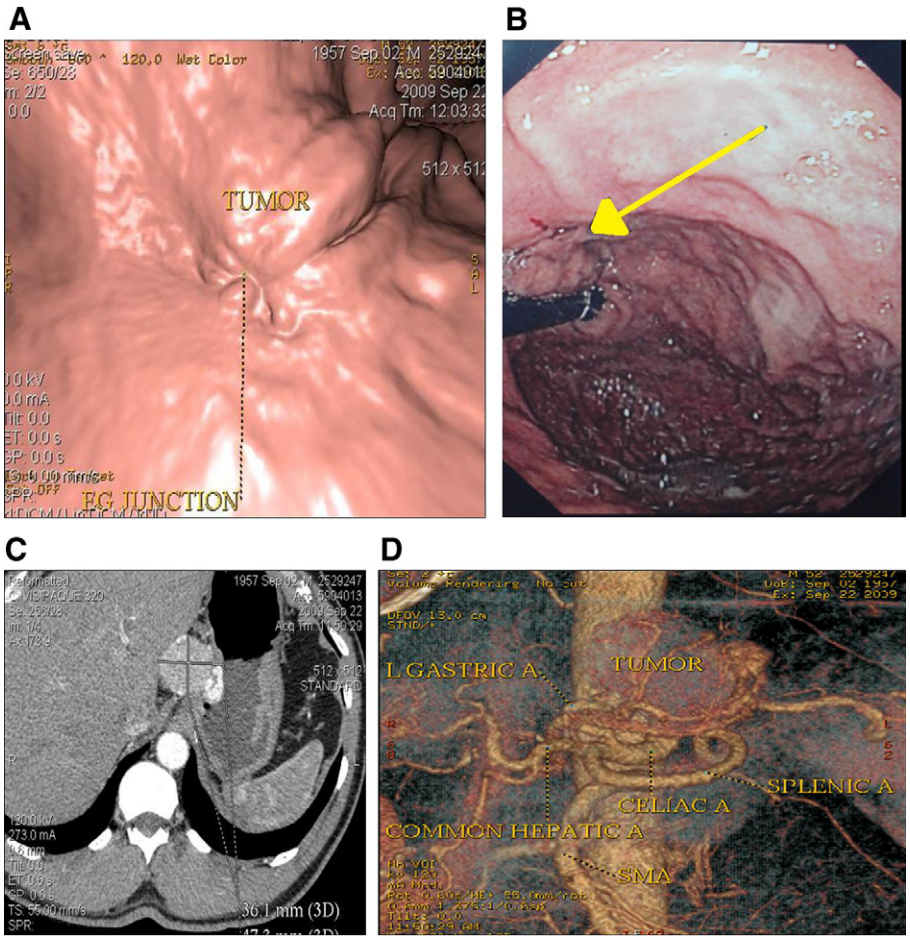

Figure 5. (A–C) Endoluminal image (A), gastroscopic image (B), and corresponding 2-dimensional axial scan (C), showing the tumour on the lesser curvature of the fundus abutting the esophagogastric junction (arrow, B). (D) A 3-dimensional arterial road map, showing a vascular tumour supplied by the left gastric artery. This figure is available in colour online at http://carjonline.org/.

experience with preoperative planning for laparoscopic resection of aggressive gastric tumours because only 2 of 11 patients who had resections had carcinoma, and we had no patients with lymphoma or sarcomas. Finally, we started vascular road mapping with patient 11 and did not have sufficient data to assess its usefulness. Nevertheless, we believe that abdominal CT with the addition of CTG and MPR can provide comprehensive information by a single data acquisition for various gastric tumours by combining information obtained from the combination of conventional abdominal CT, upper-gastrointestinal series, and optical gastroscopy. A larger series is necessary to determine the clinical role and usefulness of CTG and vascular road mapping in surgical planning.

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